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## Introductory Remarks

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## Introductory Remarks

### **Abstract**

This philosophy and directions of the DARPA/AFML Interdisciplinary program for Quantitative NDE are reviewed and the structure of this review meeting is summarized. I would like to make a few, very general, introductory remarks about the philosophy of the Quantitative NDE program and to point out some important features of the meeting this week.

### **Keywords**

Nondestructive Evaluation

### **Disciplines**

Materials Science and Engineering

## INTRODUCTORY REMARKS

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### ABSTRACT

This philosophy and directions of the DARPA/AFML Interdisciplinary program for Quantitative NDE are reviewed and the structure of this review meeting is summarized.

#### Philosophy of Interdisciplinary Program for Quantitative NDE

I would like to make a few, very general, introductory remarks about the philosophy of the Quantitative NDE program and to point out some important features of the meeting this week.

The major reason for developing a quantitative NDE capability is so that strengths or lifetimes can be predicted with as high an accuracy as possible. Figure 1 reviews the steps that are required to predict lifetimes in metals under conditions of cyclic fatigue. The core of the prediction is a failure model, such as fracture mechanics. In order to apply this, one typically needs three types of inputs: environmental considerations, such as stress levels, which are often determined by design; material properties such as toughness, which can be determined from handbooks; and flaw sizes and orientations. Determination of the latter, typically, has been the problem area. That deficiency stimulated the initiation of the Quantitative NDE program several years ago. During this week, the present status of techniques to determine flaw size and orientation, and other input parameters required by specific failure models, will be reviewed.

and failure modeling in nondestructive prediction of lifetime or strength.

Figure 2 illustrates the latter point a little bit more completely. What the ultimate user of a material system wants is an accept/reject criteria to tell him whether he can accept or reject a part. This can be required during the manufacturing process or after a period of service life. Such a decision must be based on a life prediction. As noted in Figure 1, a deterministic life prediction requires three inputs: environment, material, and flaw descriptors. In Fig. 2, the former two have been combined under the heading failure modeling and the flaw parameters have been highlighted by placing them in a separate box. This is labeled measurement science and consists of inversion techniques whereby flaw parameters are estimated from nondestructively measured data.

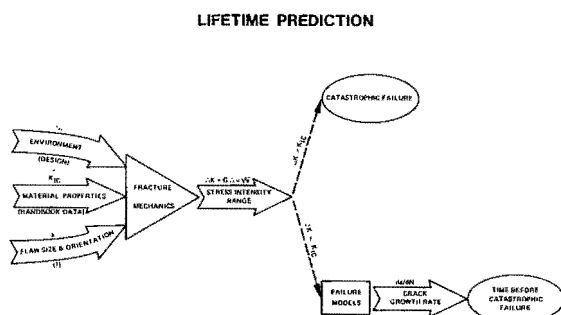


Figure 1. Life prediction.

The meeting, however, does not focus just on the determination of flaw size and orientation, because that does not stand by itself. The results of this determination must be coupled to the failure modeling, and so a number of papers will be included which are concerned with the close interaction between nondestructive measurement

#### ELEMENTS OF DEVELOPMENT OF QUANTITATIVE ACCEPT/REJECT CRITERIA

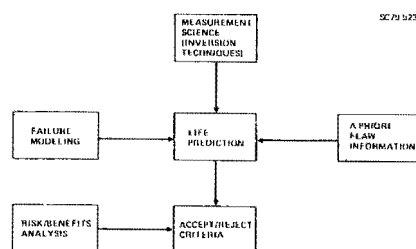


Figure 2. Steps required to establish accept/reject criteria.

In reality, life prediction can never be done in a fully deterministic fashion. Uncertainties

in all of the three inputs imply that only statistical predictions of lives can be made. In the case of flaw sizing, this occurs even with no measurement error, because sufficient information cannot always be obtained to unambiguously determine the necessary parameters. If independent, a priori information about the flaw state can be obtained, this will allow more accurate predictions to be made. The opportunity to use such information is explicitly indicated in the figure. Many measurement techniques do this implicitly. Since one seldom measures enough about a flaw to say unambiguously what it is, one is often injecting some experience or other biasing information while interpreting signals. It would be desirable to formalize and quantify this process.

Once a life prediction is made and the probabilities of various errors are defined, one needs to use some sort of risk/benefits analysis to set the ultimate accept/reject criteria. This is shown at the bottom of Fig. 2. In building a foundation for such capability, the measurement sciences aspects have been emphasized since they have been judged to be the weakest link. Other elements have been introduced insofar as they are needed to complete this scenario.

Figure 3 presents a brief summary of the evolution of a quantitative ultrasonics capability over the last several years. Any new technology should be based on building blocks of fundamental knowledge. These then combine to produce generic long term capabilities. For example, basic theories of energy flow interactions, verified by experiments, lead to an understanding of this interaction. This understanding, coupled to inversion theories, leads to new techniques to characterize flaws. Finally, if engineering developing is added, prototype, and ultimately on line, systems result.

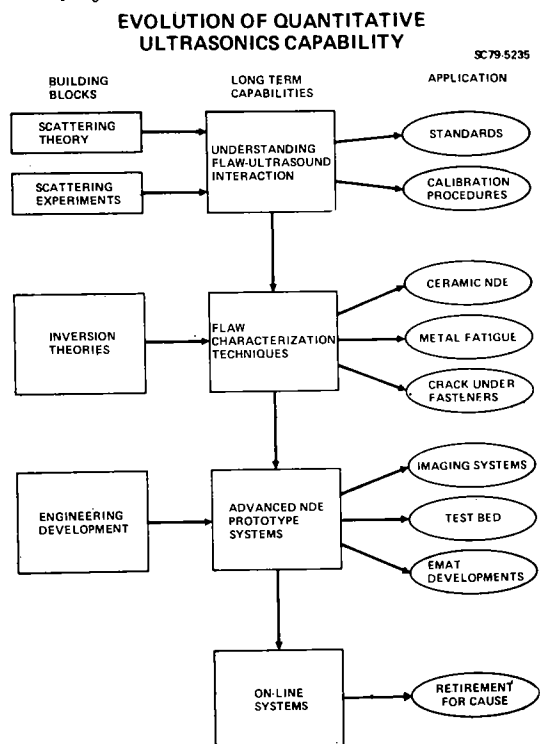


Figure 3. Evolution of quantitative ultrasonics capability.

On the far right of the figure are listed some specific applications that have arisen as a result of this program. Some of these were in the early days of the work, such as development of new standards and calibration procedures. More recently there has been applications of the NDE of ceramics, measurement of metal fatigue, and detection of cracks under fasteners. In the systems area, imaging systems, test beds and some EMAT systems have all been developed. Many of these are ongoing efforts which will be discussed throughout the meeting.

A new concept that has received a high level of attention during the last year is the concept of Retirement-of-Cause. The first session today will discuss the present effort in this area. This is an area in which quantitative techniques can have a very important and very quantifiable impact on a major DOD system.

#### Structure of the Meeting

Figure 4 presents the program of the meeting. A few remarks about its organization are in order. The first day and a half are concerned with the tight coupling between NDE and fracture mechanics or other failure models. The Retirement-for-Cause session will include three papers. The first will discuss some specific plans, being developed by the Air Force and DARPA, which are directed toward incorporating NDE in a system to inspect in-service turbine disks and return them to service if no flaw likely to produce failure is found. The success of such an approach depends both on the accuracy of the NDE and the failure modeling. The next two papers address these questions. The second discusses evaluations of the reliability of NDE and its coupling to fracture mechanics, and the third discusses the modeling of crack initiation and use of the results in lifetime predictions.

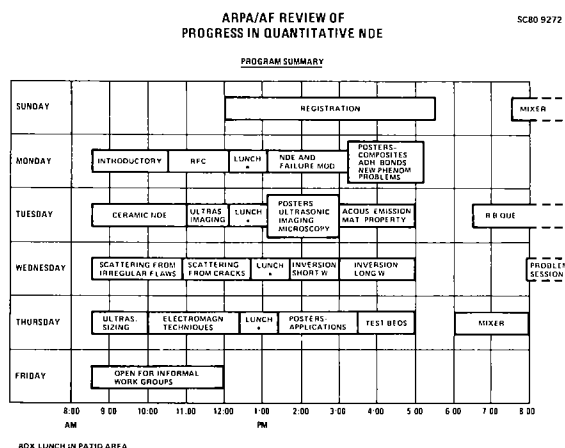


Figure 4. Meeting program.

An important talk in the afternoon session on coupling of NDE and failure modeling will present a proposed strategy for NDE of adhesive bonds. This talk is the result of a planning activity that has been in progress over the last year. Since the subject is an old one that has thus far defied solutions, a significant period has been allowed

for discussion. A broad range of inputs are required to formulate the best possible strategy.

In the ceramics session, we are fortunate to have a paper which was not in the program. Bill Reynolds from the NDE Center at Harwell in England will be with us, and he has consented to give an impromptu report on some of the very interesting microfocus x-ray results that have recently been obtained at that laboratory.

From that point, about two days of technique-oriented papers will be presented: ultrasonic imaging, acoustic emission and material properties, ultrasonic scattering and inversion, and some electromagnetic techniques.

Finally, during the last part of Thursday, application and test bed programs will be discussed. These represent some ongoing programs to transfer quantitative NDE technology into practice.

This meeting has always been characterized by extremely positive technical interchanges between participants from government, industry, and university. This is a very important part of the meeting. Please feel encouraged to exchange thoughts at lunch times, during poster sessions, or any other convenient time.

#### Closing Comments

It has always been important to receive feedback on the directions of a research program. I would be extremely interested in receiving any comments, particularly from users of this technology, regarding areas that should be emphasized more or should be emphasized less, and regarding directions of research which should be pursued to provide the best scientific foundation for the systems that are being developed for the future.